

THE MEDIATING EFFECT OF WORKING MEMORY IMPAIRMENTS ON THE  
RELATIONSHIP BETWEEN RUMINATION AND DISTRESS

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### The Mediating Effect of Working Memory Impairments on the Relationship between Rumination and Distress

Conceptualizations of psychopathology provided in various versions of the Diagnostic and Statistical Manual (DSM) of the American Psychiatric Association are not entirely based on empirical research (Cuthbert, 2005; Sanislow et al., 2010; Wakefield, 2016). While each version of the DSM has had a fair share of criticism from scholars, the most controversial version of the DSM to date is the DSM-5. Although this edition brought forth a multitude of changes (e.g., changes to the structure and organization of disorders, additions of new disorders, and changes to diagnostic criteria for many disorders), there were still many unresolved issues with the classification system (Wakefield, 2016). There appear to be four main concerns with DSM conceptualizations: heterogeneity of symptoms within disorders, homogeneity of symptoms among disorders (i.e., cross-cutting symptoms), an unclear clinical significance of subthreshold symptomology, and substantial comorbidity.

DSM-5 conceptualizations treat disorders as discrete entities that can be separated into categories (Trull & Durrett, 2005). The presence of mental illness is determined using a list of polythetic, observable, attributes and symptoms (usually five to seven). To meet criteria for a disorder, an individual must be experiencing a pre-specified number of symptoms (e.g., three out of five criteria). Thus, two individuals with the same diagnosis may have little symptom overlap. This is problematic, as research has demonstrated that variance in combinations of symptoms within categorically distinct disorders is associated with differential responses to treatment (Krueger & Bezdjian, 2009). This has lead researchers to debate the extent to which the DSM classification scheme is valid for research and practice (Wardenaar & de Jonge, 2013).

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In addition to substantial heterogeneity of symptoms within disorders, the same observable behaviors may be used to diagnose more than one categorically distinct disorder (e.g., panic and avoidance behaviors are used to diagnose both personality disorders and certain anxiety disorders; Clark, Watson, & Reynolds, 1995). The DSM-5 partly tried to address this issue by including a self-report measure called the DSM-5 Level 1 Cross-Cutting Symptom Measure (American Psychiatric Association, 2013). The purpose of the measure is to assess the presence of symptoms that occur across a variety of domains of psychopathology in research (i.e., cross-cutting symptoms). However, this measure is not meant to be used for the sole diagnosis or screening of disorders, which subsequently makes it unclear how clinicians should use the information obtained from the measure (Clarke & Kuhl, 2014). In sum, the DSM-5 does not provide empirically-sound explanations for why disorders may or may not share features.

Using lists of symptoms identified as either present or not present to identify disorders within a categorical framework poses additional challenges. Most notably, diagnoses using DSM classifications do not provide information regarding the extent to which symptoms exist within proximity of a clinically-relevant threshold (Krueger & Bezdjian, 2009). Thus, if an individual is presenting with symptoms of psychopathology, but there aren't enough symptoms present to make a diagnosis (e.g., only 3 out of 10), or symptoms are not severe enough to meet criteria (e.g., mild impairment associated with presenting symptoms), there may be no diagnosis provided. However, information about subthreshold symptoms of psychopathology has long been shown to be useful for identifying risks of maintaining and developing psychopathologies later in life, and thus may be useful for clinicians in providing treatment (Turner, Beidel, Borden, Stanley, and Jacob, 1991; Clark, Watson, and Reynolds, 1995; Judd et al., 1998; Striegerl-Moore et al., 2000; Dell'Osso, Allen, & Hollander, 2005; Friederich et al., 2007). The DSM-5 attempted

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to capture aspects of subthreshold symptomatology by introducing new disorders, subtypes, and specifiers (Krueger & Bezdjian, 2009). For example, the DSM-5 introduced an “Anxious Distress Specifier” for bipolar and related disorders, which can be used to specify that the individual is presenting with anxiety symptoms that aren’t part of the bipolar/related diagnosis, but don’t meet criteria for a comorbid anxiety disorder. However, a problem with this approach is that additions of new categorical classifications can cause further overlap with other disorders. Jones (2012) gives an example of where this was the case in previous versions of the DSM, where the adding a “generalized” specifier for individuals with social phobia to signify the presence of general social fears overlapped heavily with the diagnostic criteria for avoidant personality disorder. Thus, other methods to address subthreshold symptoms of psychopathology might be preferable.

The DSM also neglects to provide empirically-based rationales for why categorically distinct disorders co-occur, which is troublesome since being diagnosed with more than one disorder is typical (Widiger & Shea, 1991; Neale & Kendler, 1995; Kim & Eaton, 2015). It is surprising that there have not been attempts to address this issue, as there has been a plethora of neuroscience and genetics research conducted that provide robust evidence for shared liabilities that contribute to psychopathology (Caspi et al., 2014). For example, research has demonstrated using samples of twins that mood and anxiety disorders are influenced by the same genetic characteristics (Kendler et al., 1992; Hettema et al., 2005). Further, models that lump mental illnesses together, as opposed to splitting them into discrete categories, have shown that many disorders share core features and risk factors. These models consistently demonstrate many disorders are phenotypically more alike than not (Hyman, 2007). The strong etiological relationships between diagnoses has left some researchers to question whether comorbidity is a

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valid term to use in the context of psychopathology and the DSM because there is little evidence available to determine if disorders truly present as distinct entities (First, 2003). However, there has not yet been a version of the DSM that integrates these findings into the overall structure and organization of disorders.

Hierarchical dimensional models of psychopathology can overcome many of the shortcomings of DSM conceptualizations (Cuthbert, 2005). Dimensional models can be used to display relationships between core features of disorders, shared symptoms of disorders, and shared vulnerabilities that contribute to disorder development, onset, and maintenance. By focusing on each of these different topics, dimensional models may differ in the extent to which they hierarchically organize information in terms of higher-, intermediate-, or lower-order constructs. Dimensional models may statistically test relationships among sets of symptoms ranging in severity, personality trait dimensions, cognitive risk factors, genetic vulnerabilities, and biological markers (Clark, Watson, & Reynolds, 1995). Thus, dimensional models may be used to answer questions about heterogeneity of symptoms within disorders, cross-cutting symptoms, subthreshold symptomatology, and disorder covariation.

One approach researchers have pursued using dimensional models is to map DSM symptoms and criteria that would traditionally be diagnosed as present/not present onto a continuum of some criteria (e.g., based on severity of impairment). These dimensions of symptoms may then be connected to intermediate- and higher-order constructs that represent core features of psychopathology (e.g., distress, emotional instability; Krueger, 1999). However, these models do not always align well with DSM categorizations. This is in-part because, as previously described, categories in the DSM do not account for etiological underpinnings of psychopathology or individual differences in subthreshold symptomatology (Krueger &

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Bezdjian, 2009). Moving from DSM conceptualizations to a dimensional system of classification is a monumental task. The process of developing a unitary dimensional model calls for a massive overhaul of research to accomplish. Further, it has been suggested that this process should not be done haphazardly, but rather research should target and build off specific domains of psychopathology where DSM conceptualizations have been consistently demonstrated to be lacking (Clark, Watson, & Reynolds, 1995).

### **Conceptualizations of Mood and Anxiety Disorders**

Mood and anxiety disorders are some of the most commonly diagnosed disorders in the United States (Conway, Compton, Stinson, & Grant, 2006). It has been estimated that roughly 50% of individuals meet threshold/subthreshold diagnostic criteria for depression or anxiety. Further, it has long been recognized that most people who experience anxiety (up to 85%) also demonstrate threshold/subthreshold symptoms of depression, suggesting substantial comorbidity (Angst, Merikangas, & Preisig, 1997; Gorman, 1997; Kaufman, 2000). Treatment, research, and diagnosis of mood and anxiety disorders can be particularly difficult for clinicians because symptoms greatly overlap (Gorman, 1997).

Many categorically distinct mood and anxiety disorders can be classified according to the same corresponding cognitive impairments, including the tendency to utilize dysfunctional cognitive styles of thinking to regulate negative emotions and decreased experiences of positive affect (Hofmann, Sawyer, Fang, & Asnaani, 2012). Further, work using functional magnetic resonance imaging and electroencephalogram (fMRI and EEG, respectively) has demonstrated that mood and anxiety disorders may also be linked by liabilities that underlie brain circuits involved in cognition (Nemeroff et al., 2013; Iorfino et al., 2016). However, the DSM-5 does not organize disorders based on these findings. Instead, the DSM-5 categorizes disorders based on

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supporting diagnostic validation and reliability research (Goldberg, Krueger, Andrews, & Hobbs, 2009). The strong similarities among the organizationally distinct classes of mood and anxiety psychopathology in the DSM have lead researchers to question if there should be clear diagnostic boundaries between certain disorders. Alternatively, some have instead proposed disorders work in tandem and should be thought of in terms of higher-order dimensional constructs that unite them (Kotov et al., 2015).

Over the last 20 years there has been strong factor-analytic evidence provided to support that mood and anxiety psychopathology can be classified under one fundamental dimension, the internalizing spectrum (Krueger & Markon, 2006). The internalizing spectrum is comprised of disorders categorized by diminished responses to positive affect and excessive responses to negative affect. These disorders include major depressive disorder, dysthymic disorder, generalized anxiety disorder, post-traumatic stress disorder, panic disorder, agoraphobia, social phobia, and specific phobia. Hierarchical dimensional modeling has shown this spectrum may be further divided into two subfactors: a distress component and a fear component (Kessler et al. 2011). As the names imply, individuals with distress psychopathology tend to internally respond to feelings of distress associated with increased negative affect or dampened responses to positive affect (e.g., anxious, moody, unhappy), while individuals with fear psychopathology tend to internally respond to feelings of fear associated with increased negative affect (e.g., panic). Models investigating the a two-factor structure of psychopathology that utilize the internalizing spectrum have been empirically supported using samples of adults (Kreuger & Markon, 2006) and children (Lahey et al., 2008). However, there are also areas that dimensional models may be improved upon. Much of the work done to develop the two-factor model of psychopathology (e.g., Clark & Watson, 1991; Krueger, 1999; Watson, 2005; Krueger &

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Markon, 2006) has yet to connect many findings from neuroscience research to fundamental spectra and subfactors (Vaidyanathan, Patrick, & Cuthbert, 2009).

To summarize, there has been a poor integration of empirical research into categorical conceptualizations of mood and anxiety psychopathology. Dimensional models of mood and anxiety disorders can address many of these issues. However, because these models are relatively new there is substantial room for growth in terms of connecting shared biological liabilities and observable behaviors to proposed fundamental dimensions. In the context of mood and anxiety disorders, research has continually supported that dysfunctional cognitive styles of thinking used to regulate emotions (e.g., rumination and worry) are in part responsible for depression and anxiety (Hoffmann et al., 2012). Thus, one logical place to begin to build on dimensional models of mood and anxiety psychopathology is to investigate what neurologically causes these disorders share these tendencies.

### **Ruminative Thinking as a Shared Cognitive Symptom of Mood and Anxiety Disorders**

Rumination is a problematic style of repetitive negative thinking (RNT) that is common in mood and anxiety disorders (Onraedt & Koster, 2014). Rumination can be defined as maladaptive, recursive thinking about negative emotions and symptoms of distress (Rippere, 1997). Research has shown rumination maintains symptoms of psychopathology in major depressive disorder (MDD; Newby & Moulds, 2012), generalized anxiety disorder (GAD; Ruscio, Seitchik, Gentes, Jones, & Hallion, 2011), post-traumatic stress disorder (PTSD; Spinhoven, Penninx, Krempeniou, van Hemert, & Elzinga, 2015), dysthymic disorder (Kelly, Matheson, Ravindran, Merali, & Anisman, 2007), somatization disorders (Brosschot, 2002), and eating disorders such as bulimia and binge-eating disorder (Nolen-Hoeksema, Stice, Wade, & Bohon, 2007).



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Rumination has also been studied in relation to core constructs that make up the basis of the internalizing spectrum proposed by researchers such as Krueger & Markon (2006). Of the most widely studied is the relationship between rumination and increased experiences of negative affect (Whitmer & Gotlib, 2013). Negative affect can be defined as a disposition to experience negative emotional states (Watson & Clark, 1984). For instance, feelings of negative affect such as embarrassment, sadness, helplessness, stress, and anger have all been demonstrated to be positively associated with the tendency to engage in rumination (Thomsen, 2006). As such, responses to negative affect are central to the discussion of how ruminative thinking influences mood and anxiety psychopathology.

Strong relationships between negative affect and rumination has lead researchers to ask if engaging in rumination increases negative affect, or if increases in negative affect are responsible for inciting rumination. Research has suggested that rumination results from the continual devotion of cognitive resources towards attending to and maintaining negative thoughts and emotions in working memory (Lissnyder, Koster, & Raedt, 2011). Further, the relationship between negative affect and rumination has been demonstrated to be reciprocal, where increased ruminative thinking results in increased negative affect (Whitmer & Gotlib, 2013).

Early work by Duval and Wicklund (1972) proposed the Theory of Self-Awareness to explain the relationship between self-focused attention (SFA) and affective states. This theory posits that when a person is self-aware (i.e., thinking about their emotions or state of being), an individual's current state in a specific domain is compared with their standard or ideal state for that domain. From this framework, it is proposed that positive affect is experienced if the current state is better than the standard, while negative affect is experienced if the current state falls below the standard. Similarly, Carver and Scheier (1998) proposed that negative affect occurs

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from self-regulatory processes that allow an individual to identify when slow progress is made towards reducing the difference between the current state and the standard state. In sum, these theories posit that when an individual engages in rumination, the individual compares their ideal state to the current or past state, recognizes that the states are incongruent (and ruminates about why this is the case), experiences negative affect because of ruminative thinking, and thus ruminates more about their negative emotions, creating additional negative emotions. This process can be thought of as a downward-spiraling loop (Nolen-Hoeksema, 1991).

Supporting that there is a reciprocal relationship between ruminative thinking and negative affect, Nolen-Hoeksema (1991) proposed that for individuals with depression, ruminative SFA results in prolonged depressive states because rumination enhances the effects of negative affect on cognitive processes. Many researchers suggest that in anxiety and related disorders, ruminative thinking seems to increase negative affect by way of continual devotion of cognitive resources towards negative content (Watson, Kotov, & Gamez, 2006). This idea has lead researchers to explore the extent to which deficits in cognitive functioning may contribute to an individual's inability to avoid or cease ruminative thinking.

### **Cognitive Vulnerabilities Associated with Rumination and Distress Psychopathology**

A discussion of information processing is key to understanding how the rumination cycle occurs. Rumination can be described as a style of information processing centered on recurrent thoughts and ideas (Monnart, Korneich, Verbanck, & Campanella, 2016). However, it is well established that an individual's information processing resources are limited, such that an individual may only attend to and hold in working memory a certain amount of information present in the environment at any given time (Bargh, 1982).

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Working memory (WM) has been defined as the temporary limited-capacity information storage system that provides a workspace for information to be processed, during which information may be temporarily maintained and manipulated (Baddeley, Banse, & Huang, 2012). Further, information held in this workspace reflects an individual's focus of attention and representations of awareness (Joorman & Quinn, 2014). Executive functions carried out by WM are responsible for various distinct, but related control processes that select what information may enter and remain in working memory (Joormann, Levens, & Gotlib, 2011). For example, executive functions are responsible for integrating processes that ignore irrelevant information (inhibition), altering and maintaining representations of information (updating), and switching attention between active representations (shifting; Carriedo, Corral, Montoro, & Herrero, 2016; Nee et al., 2012). These processes all require substantial cognitive resources that are used up when a person engages in rumination (Flores Jr. & Berimbau, 2016).

Rumination is thought to be distinctively associated with poor working memory performance (Owens, Koster, & Derakshan, 2012). For example, work by Curci, Lanciano, Soleti, and Rimé (2013) found that ruminative processes drain working memory (WM) resources by dividing attention, leading to decreases in WM performance. Following this framework, one would infer that during a state of rumination an individual would have less working memory resources available, and as a result would perform poorly on tasks of executive functioning due to a lack of resources. Thus, it is believed the inability to prevent intrusive, negative thoughts from entering working memory (i.e., inhibition) and the inability to replace these thoughts (i.e., update working memory) contributes to ongoing ruminative thought (Joorman, 2006).

In keeping with the notion that rumination is associated with negative emotional experiences, a myriad of research has established that trait ruminators show biases towards

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processing negative stimuli. Specifically, it has been demonstrated that individuals high in trait rumination devote more neural resources when processing negative information compared to neutral or positive information (Judah, Grant, & Carlisle, 2016; Cooney, Joorman, Eugene, Dennis, & Gotlib, 2010). Similarly, many studies have also shown that individuals with distress psychopathologies have biases for maintaining negative information over other neutral or positive information held in working memory (Whitmer & Gotlib, 2013). For example, a study conducted by Levens & Gotlib (2010) found that depressed individuals updated sad material in working memory faster than non-depressed individuals. Similar findings have been replicated for individuals with trait anxiety, where increased anxiety was shown to be associated with biased working memory updating for negative information (Visu-Petra, Miclea, & Visu-Petra, 2013).

The results from these studies suggest that biases for maintaining negative information in working memory is likely responsible for the maintenance of ruminative thought cycles in distress psychopathology (Onraedt & Koster, 2014). More specifically, if a person is unable to ignore or orient attention away from negative information held in working memory and devote resources to update and incorporate new, more neutral or positive information, then prolonged exposure to negative contents may result in increased negative affect, resulting in further ruminative thought (Koster, Lissnyder, Derakshan, & Raedt, 2011). However, one criticism that has been made of the aforementioned research is that researchers typically only use behavioral measures to assess working memory functioning. This is problematic, as it makes it impossible to develop nuanced interpretations regarding how deficits in executive functioning relate to ruminative thinking. Specifically, it is impossible to distinguish between early and late processes involved in executive functioning (e.g., attentional shifting vs. actively manipulating information) using reaction time data. This is because research conducted using reaction time as

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a proxy for attention not only captures attentional processes, but also includes error resulting from non-attentional processes (Judah, Grant, & Carlisle, 2016).

**Measuring Cognitive Vulnerabilities.** Electroencephalogram (EEG) methodologies provide a more desirable way to obtain a measure of executive functioning compared to behavioral measures. This is because neurophysiological techniques can provide insight into temporal aspects of processing that behavioral equivalents do not. EEG researchers often opt to use event-related potential (ERP) methodology because of the ability to obtain a time-locked measure of neural activity to an external stimulus. ERPs measure summated postsynaptic potentials produced by synchronous firing of cortical pyramidal neurons. The summated voltages produced throughout the brain are represented by ERP waveforms. ERPs can be distinguished by timing, morphology, and scalp topography in response to experimental manipulations (Hajcak, MacNamara, & Olvet, 2010). Further, ERPs can be used to distinguish between early and late process, including processing occurring within the first 100 milliseconds of seeing a stimulus (Sur & Sinha, 2009). This makes ERPs useful for quantifying specific executive functions carried out in working memory (Kessel et al. 2016). For example, researchers have suggested that the P300 ERP waveform may be used to measure neural resource allocation during working memory updating, which occurs approximately 250-450 ms after the stimulus presentation (Polich, 2007). In these studies, greater P300 amplitudes correspond to greater resource expenditures during updating (Donchin and Coles, 1988; Kessel et al., 2016). Thus, the P300 may be used to obtain a measure of resource allocation during working memory updating in response to emotional stimuli.

Kessel and colleagues (2016) demonstrated how a measure of working memory updating can be obtained using EEG/ERP methodology. Specifically, the researchers had participants

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complete an N-back task while EEG data was collected. During N-back tasks, participants are rapidly shown a series of stimuli (e.g., words, pictures). As participants are shown stimuli from the series, participants are asked to decide if a target stimulus on the screen matches previously shown targets that appeared N steps prior (e.g., a 3-Back task means participants have to recall stimuli that appeared 3 steps prior). This type of task requires participants to add and subtract information from working memory, as participants must attend to, update, and store the information so that it may later be retrieved for decisions (Desnoyers & Arpin-Cribbie, 2015). The experimental design utilized by Kessel and colleagues (2016) poses a way to corroborate findings from behavioral studies regarding relationships between rumination, distress psychopathology, and working memory updating.

### **The Current Study**

Conceptualizations of mood and anxiety psychopathology in the DSM do not adequately address findings from neuroscience and genetics research. Additionally, high comorbidity of disorders is not addressed. Dimensional models may be used to address these shortcomings by statistically testing relationships between disorders and related phenomena. However, few studies using dimensional models have yet incorporated findings from neuroscience and genetics research.

The present project aimed to contribute to dimensional models of psychopathology by connecting styles of thinking typical for mood and anxiety disorders to deficits in brain functioning. Specifically, no research was found that adequately investigated the possibility that biases in working memory updating for negative information maintain ruminative thinking for those residing on the lower, middle, and upper ends of the distress dimension. Instead, much research that has investigated relationships between rumination, executive functioning, and

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distress psychopathology has done so in the context of DSM criteria for categories of disorders (e.g., groups with individuals being having present/not present depression or anxiety alone; see Joormann, Levens, & Gotlib, 2011; Joorman and Gotlib, 2008; Whitmer & Gotlib, 2013). This kind of approach does not allow for any information to be obtained regarding relationships between dimensions of psychopathology and executive functioning. However, despite this, the findings from a variety of studies looking at individual disorders and trait rumination implicate similar deficits in executive functioning are responsible (Joorman, Levens, & Gotlib, 2011; Joorman & Gotlib, 2008; Lee Pe, Raes, & Kuppens, 2013; Levens & Gotlib, 2010; Whitmer & Gotlib, 2013; Visu-Petra, Miclea, & Visu-Petra, 2013).

It was hypothesized that the reason individuals prone to experience distress share the tendency to ruminate is because of difficulties updating contents of working memory. This was expected because research has suggested individuals with various distress psychopathologies have issues with “sticky thoughts,” where they are unable to devote resources to maintain positive or neutral information in working memory due to biases for maintaining negative information (Joormann, Levens, & Gotlib, 2011). Further, other research has demonstrated that emotional distress is associated with poorer working memory functioning in non-clinical populations (Stout and Rokke, 2008). These findings further support the importance of accounting for subthreshold psychopathology in dimensional models. This can be achieved by using continuous measures of functioning.

To investigate relationships between working memory updating, distress, and rumination, EEG was used to obtain a measure of working memory updating. The present study used an N-back paradigm, which was modeled after the 3-back task used by Kessel and colleagues (2016). To obtain a measure of distress psychopathology, participants were asked to complete the

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MMPI-2-RF (Ben-Porath & Tellegen, 2008/2011). This measure was selected as previous research has demonstrated that the Restructured Clinical scales of the MMPI-2-RF, specifically RCd (Demoralization), RC7 (Dysfunctional Negative Emotions), and RC2 (Low Positive Emotions) are the best predictors of the distress subdimension among all MMPI-2-RF subscales (Lee, Sellbom, and Hopwood, In Press). Participants tendency to ruminate was measured using a shortened form of the Ruminative Response Scale (RRS; McEvoy & Brans, 2013) These measures both provide continuous estimates of functioning, thus allowing for the severity of symptomology to be incorporated into the research.

The goal of this study was to test the hypothesis that the relationship between features of distress psychopathology and ruminative thinking can be explained by overarching biases for maintaining negative information in working memory. This area of research is important, as it may provide implications for dimensional conceptualizations of internalizing psychopathology. Specifically, the present study aimed to incorporate findings from neuroscience research into dimensional models of distress disorders. Additionally, the current study aimed to provide a means to address issues associated with conceptualizing subthreshold/threshold psychopathology by using a dimensional approach. This was accomplished by using continuous measures of functioning, which allowed individual differences to be fully captured and incorporated into the model.

## Method

### Participants

Pre-screen data were collected from 271 undergraduate participants enrolled in courses at a Midwestern University across the Fall 2017 and Spring 2018 semesters. Participants completed a short online survey that assessed medical health, tendencies to engage in ruminative thinking,



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and a measure of trait hopelessness. The purpose of administering the pre-screen was to identify participants with greater tendencies to ruminate and potentially clinically-relevant features of distress psychopathology (i.e., hopelessness). The pre-screen criteria required that participants had an average score on the shortened Ruminative Response Scale greater than or equal to two and total score on the Beck Hopelessness Scale (BHS) greater than or equal to six. This cutoff was selected for the BHS because scores ranging between 4-8 are used to indicate the presence of mild impairment (Beck, Weissman, Lester, & Trexler, 1974). Thus, all participants that were pre-screened should have demonstrated, at minimum, mild distress. However, these criteria were waived before the start of data collection during the Spring 2018 semester due to low recruitment and study completion rates during the Fall semester. Specifically, 71 out of 151 participants that completed the pre-screen were invited to complete the study during the Fall semester based on the pre-screening criteria. Of the 71 invited participants, 15 participants came into the lab to complete the study. Thus, the recruitment rate during the Fall semester was 21.2%. However, of the 15 participants recruited during the Fall semester, 6 had unusable EEG data because of inaccurate trigger codes on the working memory task. The trigger codes are important because they are used to time-lock the responses to the stimuli (i.e., words), and without them there was no way to obtain P300 values for the categories of words. This left 9 participants sampled during the Fall semester that had complete, usable data.

A decision was made to open the study to all participants during the Spring 2018 semester to attempt to reach the desired sample size of 30. During the Spring semester, 120 participants completed the pre-screen and were invited to complete the laboratory study. Of these participants, 13 came into the lab to complete the study. Thus, the recruitment rate during the Spring semester was 10.8%. However, of these 13 individuals, 2 decided they did not want to be

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hooked up to the EEG and left the study before data were collected. Another 2 individuals were unable to complete the EEG task because of technical issues associated with connecting the EEG electrodes to the scalp. The left 9 participants that completed both the MMPI-2-RF and the working memory task during the Spring semester. Additionally, 1 participant collected during the Spring semester had unusable EEG data because of excessive interference that caused a large majority of trials to be rejected during data cleaning (more than 50%). This left 8 participants sampled during the Spring semester with complete, usable data.

To summarize, of the 271 participants who completed to pre-screen, a total of 17 participants out of 191 invited participants (totaled across both semesters) completed the MMPI-2-RF and the working memory task. Of the 17 participants with complete data, 2 participants sampled during the Fall semester were found to have invalid MMPI-2-RF profiles, leaving 15 total participants for complete analyses (mean age = 19.13,  $SD = .99$ ). See Table 1 below for further details regarding why these participants profiles were invalid. Additionally, the invalid profiles' RCd scores are presented. Of the 15 participants with complete and valid data (7 sampled during the Fall, 8 sampled during the Spring), 6 identified as male and 9 as female. The race/ethnicity break-down for these participants was 93.3% White and 6.7% Asian. All participants who completed the pre-screen received compensation in the form of credit for an introductory course requirement. Individuals who came into the lab received additional credits for an introductory course requirement and were also entered into a drawing for a gift card.

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Table 1

## *Summary of MMPI-2-RF Profiles*

MMPI-2-RF Scale	Valid Profiles (N = 15)		Invalid Profile 1	Invalid Profile 2
	Mean (SD)	Min - Max		
CNS**	1.93 (2.25)	0 – 6	24*	16*
VRIN*	55.07 (11.04)	39 - 73	43.50	48.34
TRIN*	56.60 (6.37)	50 - 73	72.58	57.48
F*	64.07 (21.90)	42 – 106	60.55	92.40
Fp*	59.93 (16.48)	42 - 94	67.99	76.52
Fs**	2.60 (2.64)	0 – 8	2	6
FBS*	59.33 (17.95)	39 – 96	67.05	79.94
RBS*	63.73 (18.25)	33 - 92	79.75	83.97
L	50.94 (10.22)	37.29 – 66.43	42.34	37.39
K	43.19 (10.44)	31.29 – 65.60	27.86	31.29
RCd**	10.67 (9.37)	0 – 24	16	21

*Note:* Scale CNS is a measure of nonresponding (i.e., the total number of items missing).

Scale VRIN is a measure of random responding. Scale TRIN is a measure of acquiescent responding. Scales F, Fp, Fs, FBS, and RBS are measures of overreporting. Scales L and K are measures of underreporting. Scale RCd is a measure of demoralization. Scales marked by \* are rounded/truncated scores. Scales marked by \*\* are raw scores. Scales that are not marked with an asterisk are unrounded/untruncated scores. Individual profile scores for each invalid profile marked by \* were reasons why the individual profile was marked invalid.

## **Materials**

**Shortened Ruminative Response Scale.** The Ruminative Response Scale (RRS) is used to measure individual differences in the tendency to engage in ruminative thinking during a period of depressed mood (i.e., differences in trait rumination; Nolen-Hoeksema & Morrow, 1991). Participants are asked to rate 22 items that assess the individual's tendency to engage in rumination using a four-point scale ranging from almost never (1) to almost always (4). For

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example, one item asks participants to rate how often they “Think ‘Why can’t I handle things better?’”

Research using the RRS proposed the measure to consist of three factors: brooding, reflection, and depression (Treynor et al. 2004). Brooding is defined as the passive comparison between an individual’s current and ideal state, (e.g., “How often do you think ‘Why do I always react this way?’”). Reflection is defined as deliberate problem-solving with the intent to overcome low mood, (e.g., “How often do you write down what you are thinking about and analyze it?”). The last factor, depression, is composed of items that overlap with symptoms of depression, (e.g., “How often do you think about your feelings of fatigue and achiness?”). Since its initial development, research has been done to alter the RRS to remove a confound between rumination and specific symptoms of depression. To do this, items were removed that fit under the depression factor, resulting in a ten-item measure of rumination (Segerstrom et al. 2000; Treynor et al. 2004). To complement these changes, McEvoy & Brans (2013) altered the measures instructions and removed all remaining questions in the 10-item measure that mentioned the word depression. This resulted in a seven-item measure of rumination. Thus, the shortened 7-item measure provides a mean to assess rumination for all individuals, regardless if they have experienced depressed mood or not. The current study used McEvoy & Brans (2013) shortened Ruminative Response Scale. Exact instructions and questions used are available in Appendix A. Tendencies to ruminate were operationalized using participants’ average RRS scores. The average score consists of the sum of the seven items divided by the total number of items, where higher scores represent a greater tendency to ruminate. Scores may range from one to four. Past research has not provided reliability information for this measure; however, the current study obtained an estimate of internal consistency using the 271 pre-screened

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participants, which suggested that scale demonstrates acceptable reliability,  $\alpha = .81$ . A measure of internal consistency based on the sample of 15 participants is provided in Table 2 at the beginning of the results section.

**Beck Hopelessness Scale.** The Beck Hopelessness Scale (BHS) is a 20-item self-report measure used to quantify current levels of hopelessness (Beck, Weissman, Lester, & Trexler, 1974). The scale includes 11 negatively worded items (e.g., "My future seems dark to me) and 9 positively worded items (e.g., I look forward to the future with hope and optimism"). Each item is presented in a true-false response format. Scores obtained on this inventory can range from 0-20, with larger scores indicating greater hopeless. In addition to being used to pre-screen participants, this measure was used to obtain an estimate of convergent validity for the demoralization scale. An estimate of internal consistency for the present sample is provided in Table 2 at the beginning of the results section.

**Minnesota Multiphasic Personality Inventory-2-Restructured Format.** The Minnesota Multiphasic Personality Inventory-2-Restructured Format (MMPI-2-RF) is a 338 true-false measure commonly used to measure personality and psychopathology (Ben-Porath & Tellegen, 2008/2011). The total measure is composed of 51 scales; however, the current study will focus on scores obtained for the Restructured Clinical (RC) scales. These scales were selected for the current study as research has suggested that RCd (Demoralization), RC7 (Dysfunctional Negative Emotions), and RC2 (Low Positive Emotions) are strong predictors of distress disorders (Lee, Sellbom, and Hopwood, In Press). Specifically, RCd scores will be used to obtain a measure of distress psychopathology, as demoralization has been repeatedly suggested to be a defining feature of distress psychopathology (Sansone & Sansone, 2010). The Restructured Clinical Scales have been demonstrated to show acceptable reliability and validity

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in clinical and non-clinical samples (Ben-Porath & Tellegen, 2008). A measure of internal consistency for the RCd scale is provided in Table 2 at the beginning of the results section.

**3-Back task.** The proposed study measured individual differences in working memory updating using an adapted 3-back task modeled after Kessel and colleagues (2016). Participants were shown a series of negative and neutral words. For each word presented in the series, participants were instructed to indicate (Y/N) if the target word matched the word presented three words back. Each word in the series was presented individually for 500 ms, followed by a 2000 ms delay before another word was presented. Stimuli used in this task consisted of four distinct types: negative match, negative non-match, neutral match, and neutral non-match. There were 108 trials where targets matched the word presented 3 words back (54 negative matches and 54 neutral matches). There were 324 trials where targets did not match the word presented 3 words back (162 negative non-matches and 162 neutral non-matches). Trial types were equally presented across six separate blocks. Blocks were separated by three-minute breaks. P300 ERP activity in response to negative matching and neutral matching trials were compared to measure updating biases for emotional material. For a visual representation of this task, see Figure 1.

**Psychophysiological recording, data reduction, and analysis.** Continuous EEG activity was recorded using the Biosemi ActiveTwo system. The EEG was collected at a sampling rate of 1024 Hz. Recordings were taken using 72 scalp electrodes and acquired with an online reference unique to the ActiveTwo system. Using the amplifier, electrodes were referenced to a virtual ground point. Electrooculogram was recorded using two auxiliary electrodes; one was placed 1 cm below the eye, and the other 1 cm lateral to the eye. Electrode impedances were kept below 10 kOhms.

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MatLab (2014) was used for offline analysis. Data were referenced offline to the average mastoids and band-pass filtered from .5 – 55 Hz using Butterworth zero phase filters. The signal was segmented from -200 to 600 ms relative to feedback onset. Correction for eye movements and blinks was performed using Independent Component Analysis (see Onton, Westerfield, Townsend, & Makeig (2006) for a full review). Succinctly, ICA employs a series of algorithms that separate EEG signals into independent components associated with distinct cortical activity over time. Individual channels were examined for artifacts, removed pre-ICA, and interpolated after ICA. ERPs were averaged separately for the two overarching categories of words (negative and neutral). ERPs were scored using time-window averages at representative electrodes. Specifically, the P300 was analyzed based on a visual inspection of average peaks occurring between 250-650 ms for all participants at locations Fz, Cz, and Pz.

### **Procedure**

All participants were first asked to provide informed consent to participate in the research via an online survey. Consenting participants then completed a pre-screen that included the shortened RRS, the BHS, and a health-screen survey. Afterwards, participants were e-mailed to set up a time and date to complete to lab study. Once in the lab, participants completed a second informed consent form. Next, participants received verbal instructions for the study from a research assistant to complete a measure of psychological functioning (i.e., the MMPI-2-RF). Afterwards, participants completed a 3-back task while EEG data were collected. The entire lab study was completed in under two hours. The pre-screen survey took ten minutes or less.

### **Data Analysis**

A mediational analysis was conducted to examine if the relationship between scores on the RRS and MMPI-2-RF RCd scale were mediated by the difference in P300 amplitudes for

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negative words compared to neutral words. To investigate potential differences in P300 amplitudes across the three locations (Fz, Cz, and Pz), a repeated measures ANOVA was conducted. The results from this test supported there were not differences in amplitudes across locations. Thus, P300 difference scores for each location were averaged, and scalp location was not considered a variable in the analysis. Assumptions of mediation were also investigated. Mediation analysis was selected because it examines whether a relationship between two variables can be explained by some intervening variable. The SPSS macro PROCESS was used to run a series of linear regressions used to determine if mediation is present (see Hayes, 2012/2013 for further description of PROCESS). For this analysis scores on the MMPI-2-RF demoralization scale served as the criterion variable, scores on the shortened Ruminative Response Scale served as the predictor variable, and averaged differences between P300 amplitudes for negative compared to neutral words served as the mediating variable.

**Exploratory Analyses.** A one-way ANOVA was conducted to test for differences among participants collected during the Fall and Spring semesters on each self-report variable. This analysis was conducted to investigate the impact waiving the pre-screening criteria may have had on the results.

Pearson's correlation coefficients were used to demonstrate convergent validity of the demoralization measure. Specifically, relationships between demoralization and self-reported hopelessness are presented. Pearson's correlation coefficients were also used to investigate the relationship between behavioral and EEG data collected during the N-back task. Specifically, relationships between participants' average accuracy for trials, average reaction time, and differences in P300 amplitudes for negative to neutral words are presented.



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## Results

Table 2  
*Summary of Descriptive Statistics of Variables (N = 15)*

Measure	M (SD)	Min – Max	Alpha	Skewness	Kurtosis
Rumination	2.30 (.78)	1.14 – 4.00	.85	.70	.105
Demoralization <sup>1</sup>	10.67 (9.37)	0 - 24	.97	.20	-1.76
P300	.71 (1.15)	-1.21 – 3.01	-	.16	-.36
Hopelessness	6.93 (6.10)	0 - 20	.73	1.24	1.42
N-back RT	707.00 (89.54)	565.23 – 869.99	-	.04	-.90
N-back Accuracy	71.42 (6.58)	55.62 – 79.20	-	-.92	.81

*Note:* The above table displays descriptive statistics for all measures used in the study. The results support that the measures of rumination and demoralization were sufficiently reliable.

<sup>1</sup>Raw scores are presented for the present data but may be converted into t-scores for further clinical interpretations.

## Exploratory Analyses

A one-way ANOVA was conducted to investigate if there were differences between the participants recruited during the Fall and Spring semesters on the measures of trait rumination and demoralization. Results from these analyses suggested that participants recruited during the Fall semester ( $M = 2.73$ ,  $SD = .68$ ) had significantly higher scores on the RRS than those sampled during the Spring semester ( $M = 1.93$ ,  $SD = .70$ ),  $F(1,13) = 5.10$ ,  $p < .05$ , partial eta-squared = .28. Participants did not significantly differ on demoralization scores,  $F(1,13) = 3.54$ ,  $p = .08$ , partial eta-squared = .21. Specifically, participants sampled during the Fall had an average demoralization score of 15.13,  $SD = 7.98$ , while participants sampled during the Spring had an average demoralization score of 6.75,  $SD = 9.14$ . As such, while the means for these groups

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appear quite different, there was a large amount of variance in scores within groups, in addition to a small sample size, that likely lead to the non-significant finding.

There was a significant, positive correlation between demoralization and hopelessness,  $r = .70$ ,  $p < .004$  (See Table 3 below). There was also a significant, positive correlation between trait rumination and hopelessness,  $r = .76$ ,  $p < .001$ . Thus, it appears that the criteria used for the pre-screening measure aligned well with the selected measures of distress and rumination.

Table 3  
*Summary of Correlations Among Variables (N = 15)*

Measure	1	2	3	4	5	6
Rumination (1)	1	.85***	.32	.76***	.05	.16
Demoralization (2)		1	.08	.70**	-.05	.06
P300 (3)			1	.36	.30	.27
Hopelessness (4)				1	.03	-.03
N-back RT (5)					1	.60*
N-back Accuracy (6)						1

*Note:* The above table displays results from a correlation analysis investigating relationships between rumination, demoralization, P300 amplitude difference scores that were averaged across three locations, participants total score on the Beck Hopelessness Scale (BHS), participants' average reaction time, and participants' average accuracy score.

$p < .001$ \*\*\*,  $p < .005$ \*\*,  $p < .05$ \*

## Repeated Measures ANOVA

A repeated measures ANOVA was conducted to test for differences in P300 amplitudes across frontal, central, and parietal locations. The results from this test suggested there were no differences in amplitudes across locations,  $F(2, 13) = 1.25$ ,  $p = .30$ , partial eta squared = .08.

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Thus, differences in P300 amplitudes to negative compared to neutral words were averaged across the three locations. A summary of descriptive statistics all variables is located in Table 2.

### **Assumptions of Multicollinearity**

Assumptions of linearity and multicollinearity were investigated using scatter-plots and results from tests of Pearson's product-moment correlation coefficient. Scatter-plots depicting relationships between independent variables (rumination and the average P300 difference scores) and the dependent variable (demoralization) suggested that there appeared to be linear relationships between the dependent variable and independent variables. The results from this analysis suggest that the assumption of multicollinearity was not violated, as none of independent variables used in the mediation were related. Specifically, the largest correlation between any two independent variables used in the mediation (i.e., rumination and working memory updating) was moderate ( $r = .32$ ; see Table 3).

### **Independence**

The assumption of independence was not met, as the current sample was a convenience sample. This suggests that the participants data may in some way be connected (i.e., dependent). This is problematic because it can cause results to be biased in one direction or another, as opposed to creating a random distribution of scores on each measure collected.

### **Normality**

Assumptions of normality for linear regression were investigated using a histogram of residuals (See Figure 2). The histogram indicates that normality was not a major concern for the sample, as values appeared to generally follow the normal distribution curve. Histograms showing the distributions for the variables rumination, demoralization, and average P300 difference scores are presented in Figure 3.

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### **Homoscedasticity**

Assumptions of homoscedasticity (i.e., equal variances of residuals) were investigated using a series of residual plots (See Figure 4). Specifically, a plot of standardized residuals and the dependent variable (demoralization) revealed no issues with assumptions of homoscedasticity, as values were varied across the horizontal axis and did not appear to produce any pattern. A plot of standardized residuals and standardized predicted values further confirmed this.

### **Mediation Analysis**

In order to test for mediation, four relationships must be tested (Baron and Kenny, 1986). First, there must be a significant relationship between the independent variable (rumination) and the dependent variable (demoralization). Second, there must be a significant relationship between the independent variable (rumination) and the mediating variable (working memory updating). Third, there must be a relationship between the mediating variable (working memory updating) and the dependent variable (demoralization) when controlling for the independent variable (rumination). Finally, there should not be a relationship between the independent variable (rumination) and the dependent variable (demoralization) when controlling for the mediating variable (working memory updating). If the first three steps are present, but the fourth step is not, then partial mediation has occurred. In terms of effects, if there were a significant relationship between the independent variable and dependent variable, then a direct effect is present. If there were a significant relationship between the mediating variable and the dependent variable when controlling for the independent variable, then an indirect effect is present (i.e., the effect of the independent variable on the dependent variable can be completely transmitted

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through the mediator). Finally, the total effect is the sum of the direct and indirect effects. Thus, if one of these effects is significant, it is possible to also have a significant total effect.

The results from this analysis suggest that while ignoring the mediator (P300 amplitudes), there was a significant relationship between the independent variable (rumination) and the dependent variable (demoralization),  $b = 10.12$ ,  $t(13) = 5.74$ ,  $p < .001$ , 95% CI = (6.31, 13.93). However, the relationship between the independent variable (rumination) and the mediating variable (P300 amplitudes) was not significant,  $b = .47$ ,  $t(13) = 1.21$ ,  $p = .25$ , 95% CI = (-.37, 1.30). When controlling for the independent variable (rumination) the mediator (P300 amplitudes) did not significantly predict the dependent variable (demoralization),  $b = -1.75$ ,  $t(13) = -1.43$ ,  $p = .18$ , 95% CI = (-4.40, .91). When controlling for the mediator (P300 amplitudes) the independent variable (rumination) significantly predicted the dependent variable (demoralization),  $b = 10.94$ ,  $t(13) = 6.11$ ,  $p < .001$ , 95% CI = (7.04, 14.84). Thus, because the independent variable (rumination) and the mediator were not related, and the mediator did not out-predict the independent variable, mediation did not occur. As a result, there was a significant total and direct effect due to the strong relationship between rumination and demoralization, but there was not a significant indirect effect. A summary of results from the mediational analysis is presented in Table 4 below.

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Table 4

*Summary of Indirect, Total, and Direct Effects of Rumination on Demoralization (N = 15)*

Effect Type	Effect	Std. Error	t	95% CI
Total Effect	10.12**	1.76	5.74	[6.31, 13.93]
Direct Effect	10.94**	1.79	6.11	[7.04, 14.84]
Indirect Effect	-0.09	-	-	[-3.80, 1.39]

*Note:* The above table displays results from the mediation analysis. The results support that there was a significant direct and total effect of rumination on demoralization.

p < .001\*\*

### Discussion

Past research has taken a piecemeal approach to connecting rumination, distress psychopathology, and working memory updating. However, dimensional models pose an opportunity to connect and make sense of these findings. Specifically, past literature has demonstrated that biases for maintaining negative over neutral or positive information in working memory contribute to ruminative thinking (Joorman, 2006). Other work has demonstrated similar biases for updating negative information are associated with maintenance of various mood and anxiety disorders (Whitmer & Gotlib, 2013). However, no work was found that connected these findings into a cohesive model.

### Mediation Results

Results from the study did not support the hypothesis that working memory updating would mediate the relationship between rumination and distress psychopathology. Although the mediation findings provided support for previous research suggesting that rumination is strongly associated with distress psychopathology, no meaningful, predictive relationships were found between working memory updating for negative compared to neutral information and distress

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psychopathology or rumination. This was further supported by the findings that the direct and total effects were significant, but the indirect effect of rumination on demoralization was not. Correlations among variables suggested that while demoralization and differences in P300 amplitudes for negative compared to neutral words were not related, the correlation between rumination and P300 amplitudes was moderately sized ( $r = .32$ ; see Cohen, 1988 for guidelines to interpreting correlations). This correlation was positive, suggesting that as tendencies to ruminate increased, as did the average difference in P300 amplitudes between negative and neutral words. Thus, rumination is likely associated with greater resource allocation towards processing negative compared to neutral stimuli. However, it is worthwhile to note that this correlation was not found to be significant, likely due to the small sample size.

Per the results from the mediation analysis, it appears that working memory updating is not associated with rumination and experiences of distress. Some past research has suggested that alternative executive functions are primarily responsible for maintaining ruminative thought and distress psychopathologies. For example, research by Whitmer & Gotlib (2013) suggests that rumination occurs per increased attentional processes on negative information that impact the ability to redirect attention towards other information (i.e., deficits in attentional shifting). Similarly, Whitmer & Banich (2010) found that rumination is associated with difficulties inhibiting and disengaging from negative material. Finally, work by Zetsche, D'Avanzato, and Joormann (2011) suggested that while depression and rumination were associated with poorer inhibition, they were not associated with removing irrelevant negative information (i.e., updating). Thus, if the findings from these studies are accurate and updating is not associated with distress psychopathology or tendencies to ruminate, then perhaps mediation should not have occurred, and the results accurately represent these phenomena. However, there are a few

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problems with this conclusion. First, it has been shown that there are strong relationships between the conceptually distinct forms of executive functioning. For example, research by Miyake et al. (2000) showed that shifting, inhibition, and updating have strong, positive correlations with each other. Further, other research has suggested that updating highly overlaps inhibitory functioning, to the point of being almost indistinguishable (Jewsbury, Bowden, & Strauss, 2016). Thus, if inhibition or attentional switching were responsible, there would likely be notable differences in updating as well. Second, studies such as those conducted by Zetsche, D'Avanzato, and Joorman (2011) categorize individuals into either a control group or a group of individuals with a DSM diagnosis of depression. These two groups likely do not fully represent the entire dimension of distress. As a result, the findings from their study only provide information regarding how deficits in executive functioning relate to the categorical classification of depression.

The findings from the mediation analysis may also be used to support that individuals falling at the lower end of the distress dimension do not present with the same biases in updating as individuals with DSM diagnoses (i.e., individuals likely on the higher end of the distress dimension). No work was found that assessed this possibility. However, there have been many studies conducted to investigate potential differences between threshold/subthreshold internalizing psychopathologies in the context of functional impairments (Bystritsky, Khalsa, Cameron, & Schiffman, 2012). While a model including boundaries between subthreshold/threshold psychopathology does not align with a dimensional model, the findings may be useful to explain the finding that working memory updating was unrelated to distress psychopathology in the present sample. Specifically, results from these studies continue to implicate the importance of cognitive styles of thinking. For example, one study found that



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subthreshold/threshold generalized anxiety disorder can be distinguished by perceived controllability of repetitive negative thinking and perceived distress/impairment (Diefenbach et al., 2003). As such, this suggests that controllability of repetitive thought may be useful for distinguishing between individuals moderate and high on the dimension of distress psychopathology. However, no work was found that investigated these differences in the context of neurocognitive functioning underlying repetitive thinking. Thus, it is possible that working memory updating may only be implicated in more severe distress psychopathologies where a greater perceived inability to control ruminative tendencies is associated with poor working memory updating. If this is the case, then it is possible that working memory updating may only be implicated for individuals falling on the higher end of the distress dimension. Support for this notion would require substantial future research encompassing findings from clinical and non-clinical populations, so that the full range of the dimension could be sampled. Additionally, the costs and benefits for patients of using this kind of method to identify the presence of psychopathology should be heavily scrutinized.

There are also potential explanations for why the results from this study may not accurately represent these phenomena. One possibility is that the 3-back task was too cognitively taxing to capture differences in neural resource allocation associated with the experimental design. Three-back tasks require greater cognitive loads (i.e., cognitive resources) to maintain information compared to 2-back or 1-back tasks (Owen, McMillan, Laird, and Bullmore, 2005). Further, research has suggested that as cognitive load increases on 3-back tasks, as do P300 amplitudes. The increase in cognitive load and corresponding P300 amplitudes has been suggested to reflect exhaustive serial processing (Watter, Geffen, & Geffen, 2001). During exhaustive serial processing, the individual would search all contents of working memory to

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determine if a stimulus (e.g., a word) matches the stimulus shown three stimuli prior (Garcia-Marques, Hamilton, & Maddox, 2002). This means that during a 3-back task cognitive processes do not stop the search for the answer once identifying the correct answer, but rather do a complete search of the entire contents of working memory before coming to a decision. As a result, differences in processing negative and neutral words may not have been as apparent as they would have been during a 1-back task, as the amount of resources necessary to maintain and search through a larger cognitive load is consistently demanding, leading to consistently large P300 amplitudes. Thus, it is possible the larger cognitive load leads to less variability associated with the experimental manipulations. Some researchers have attempted to address this issue in behavioral research by using a 0-back or 1-back version as a control condition (Meule, 2017). However, in support that the task was not too difficult, participants in the present sample were, on average, 71% accurate in their classifications of words as matching or not matching a word shown three words prior. Previous research has suggested that optimal accuracy for classifying words as targets/non-targets in a 3-back task is greater than chance (i.e., 50%; Kensinger and Corkin, 2003). As such, behavioral data do not support that the task was too difficult in comparison to other 3-back tasks. Nevertheless, research has supported that 1-back and 2-back tasks are less cognitively taxing as accuracy of these tasks are much higher than 3-backs (~90%; Jacola et al., 2014). Thus, simpler n-back tasks may be more useful for measuring resource allocation during working memory updating under circumstances requiring less cognitive resources.

A second possibility is that studies investigating the contributions of working memory updating to ruminative thought have not obtained valid measurements of working memory updating. As described, behavioral studies do not allow researchers to reliably distinguish

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between executive functions including inhibition, shifting, and attention. In the present study, behavioral data were moderately correlated with neurophysiological data. Specifically, the correlation between the accuracy rate and P300 amplitudes was moderate and not significant ( $r = .30$ ,  $p = .28$ ). Further, the correlation between reaction time and P300 amplitudes was also small-to-moderate, but also not significant ( $r = .27$ ,  $p = .33$ ). These results support that behavioral data did not always align well with EEG data. Consequently, it is possible that past research which has solely used behavioral measures captured variance contributed by other executive functions, such as attentional inhibition or shifting. This possibility is supported by findings from EEG studies investigating attentional biases towards negative information in internalizing psychopathologies. For example, increased amplitudes of the P100 waveform have been found to be associated with biased processing of negative images for those with social phobias (Mueller et al., 2009). Similar findings regarding attentional biases for negative information have been demonstrated in samples of individuals with major depressive disorder (Dai and Feng, 2011). Thus, as previously mentioned, it is possible that processes such as attentional inhibition or shifting are more involved in maintaining ruminative thinking compared to updating. One benefit of the present study is that because ERP methodology was used, future research may use this same data to investigate the possibility that attentional processing is implicated. Specifically, ERPs associated with first attending to the stimulus (i.e., 100-300 ms after stimulus onset) may provide insight into early processing of negative compared to neutral information.

### **Limitations**

There are also several limitations to this study that may have contributed to the results. The first limitation is that the sample size was small ( $N = 15$ ). As such, is possible that there was not enough power to obtain meaningful results. This possibility is supported by the correlational

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finding between rumination and working memory updating, where although the correlation was moderate, no statistical significance was found.

A second limitation is that sample was not representative of the target population. Namely, although roughly half of participants (7 of the 15 total) were pre-screened to ensure endorsement of tendencies to ruminate, participants were not obtained from a clinical sample. There are clear disadvantages using undergraduate students as participants in the present research. First, although scores on the demoralization measure ranged from 0-24, the mean score on the RCd scale for the present sample was 10.67,  $SD = 2.42$ . After further reviewing the distribution of scores, only 20% of participants had demoralization scores greater than 18. Further, there was a small range of rumination scores (possible range from 1-4). Therefore, it is plausible that the reason there were not differences observed in resource allocation to negative and neutral stimuli relative to distress psychopathology and rumination is because of limited participants from an undergraduate sample with high demoralization and rumination scores. Second, undergraduate students make up a highly educated sample (Henrich, Heine, & Norenzayan, 2010). This is problematic, as education has been demonstrated to be associated with better performance on tasks of executive functioning (St. Clair-Thompson & Gathercole, 2006). Specifically, it has been suggested that better executive functioning is associated with stronger performance on tasks of literacy, writing, mathematics, and science (Bull & Lee, 2014). Thus, using a sample of participants presently enrolled in higher education greatly limits generalizations that can be drawn about executive functioning.

A third limitation of the study was the sampling method used. Specifically, because participants were only pre-screened during the Fall semester, it is possible that the participants obtained from the Fall and Spring semesters represent two entirely different samples. This

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possibility was supported by the results from the exploratory one-way ANOVA. This analysis was used to differences between the two samples on the self-report measures. It was found that the sample significantly differed on ruminative thinking, but not demoralization. This is problematic for the present research, as the assumption that scores within the sample are independent from one another is necessary to provide some sense of consistency in the results. However, because the sample was made up of two seemingly different (but highly inter-related) groups, it is difficult to say with any amount of certainty that the results are representative. Further, the sampling technique limited the ability to obtain participants high in the desired constructs, which in turn limits interpretations that can be made about these phenomena in clinical samples.

In the context of dimensional models of distress psychopathology, the present research supports that rumination may be a cross-cutting symptom of distress disorders. Although the sample size was small, the substantial relationship between rumination and demoralization provides evidence for the relevance of treating cognitive styles of thinking as a feature that makes these disorders similar. Further, while the main mediational hypothesis for this study was not supported, the methods used provide a framework for future dimensionally-oriented research to build on. Namely, future research should investigate relationships between rumination, executive functioning, and other spectra of psychopathology. This kind work is important, as it may allow for additional connections to be made between disorders that commonly covary with mood and anxiety psychopathology outside of the internalizing spectrum (e.g., alcohol use disorders; Burns & Teesson, 2002).

## **Conclusion**

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The findings from this study demonstrated that greater tendencies to experience distress is strongly associated with greater tendencies to ruminate. The results build on previous research by demonstrating that rumination is likely not unique to any one mood or anxiety disorder, but rather appears to operate as cross-cutting feature of distress psychopathologies. Rumination and features of distress psychopathology were found to be unrelated to resource allocation put forth during updating of negative information during working memory updating. Several possibilities for this finding are discussed, and all support a need for future research connecting cognitive functioning to dimensions of psychopathology.

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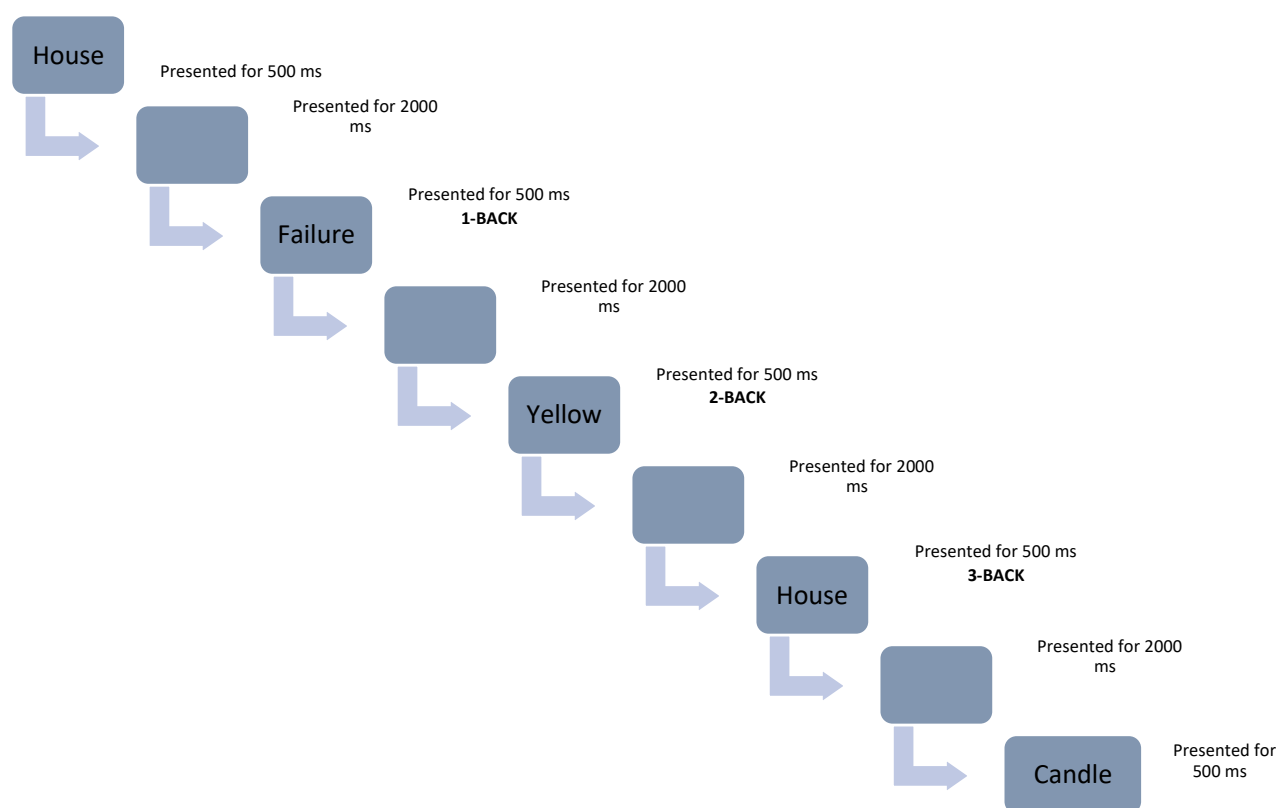
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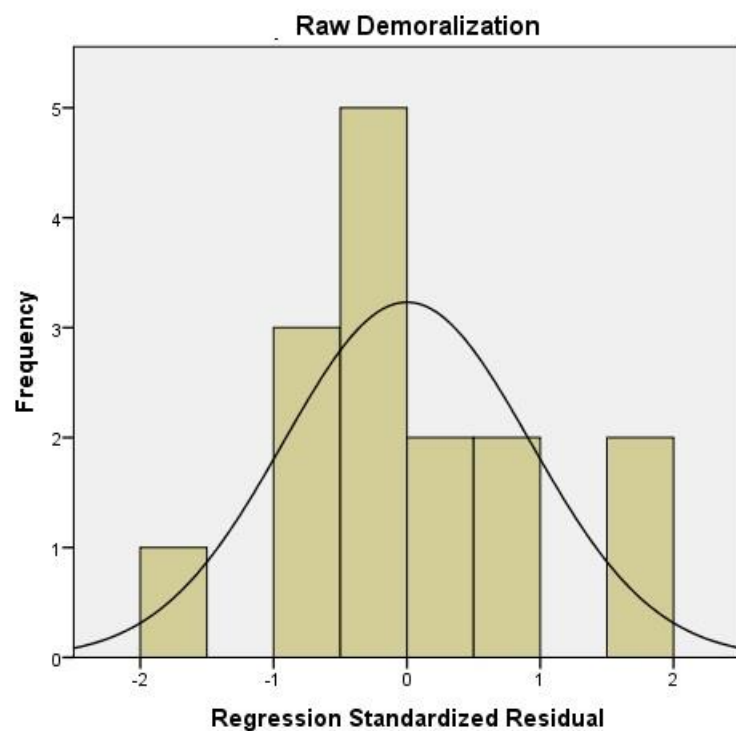
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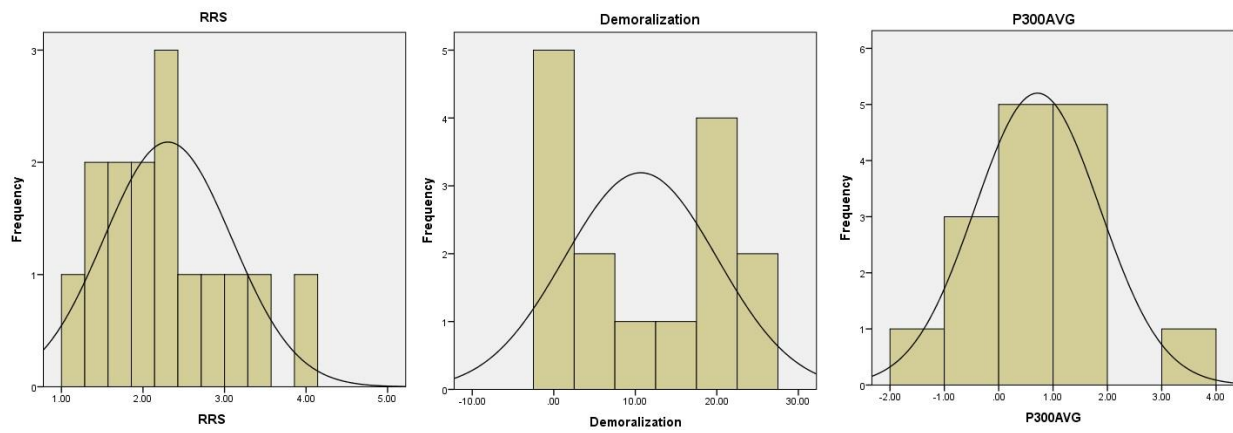
*Figure 1:* Example series of trials in the n-back task. In this task, words are presented one at a time in the center of the screen and participants are instructed to identify whether each word matches a word N words back.

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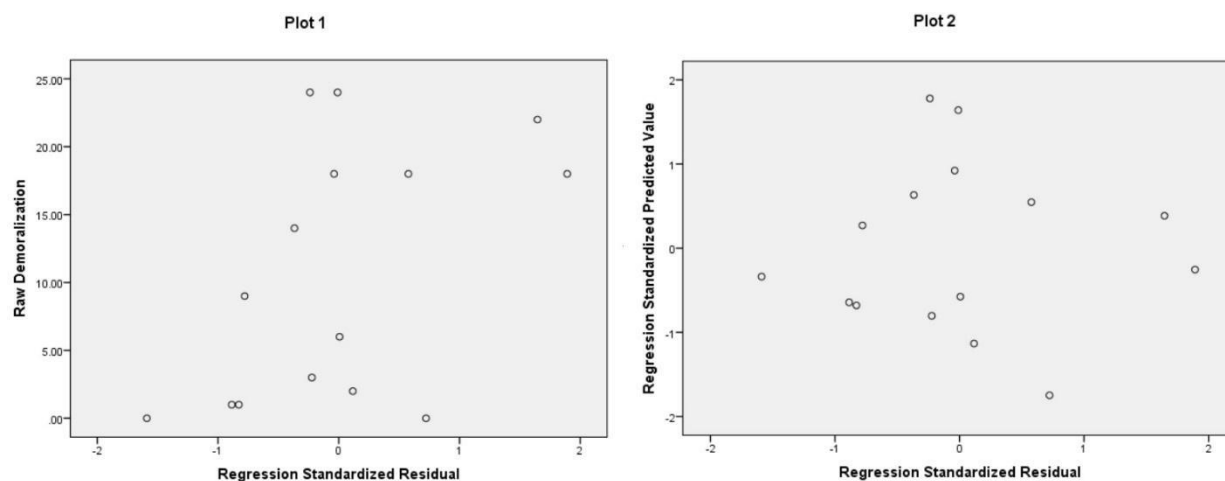
*Figure 2:* Histogram of standardized residuals for the dependent variable used to check for assumptions of normality.

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*Figure 3:* Histogram of scores on the shortened Ruminative Response Scale, the RCd Scale, and average P300 amplitudes for negative compared to neutral words.

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*Figure 4:* Plot 1 depicts the standardized residuals (x-axis) compared to the dependent variable, demoralization (y-axis). Plot 2 depicts the standardized residuals (x-axis) compared to the standardized predicted values (y-axis). These plots were used to check assumptions of the mediation.



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## Appendix A

### **Adapted Ruminative Response Scale (McEvoy & Brans, 2013)**

“People think and do many different things when they feel unhappy. Please read each of the items below and indicate whether you almost never, sometimes, often, or almost always think or do them when you feel unhappy, distressed, or bothered. Please indicate what you generally do, not what you think you should do.”

Think, "Why do I always react this way?"	(1) almost never <input type="radio"/>	(2) sometimes <input type="radio"/>	(3) often <input type="radio"/>	(4) almost always <input type="radio"/>
Think about a recent situation, wishing it had gone better	(1) almost never <input type="radio"/>	(2) sometimes <input type="radio"/>	(3) often <input type="radio"/>	(4) almost always <input type="radio"/>
Think, "Why do I have problems other people don't have?"	(1) almost never <input type="radio"/>	(2) sometimes <input type="radio"/>	(3) often <input type="radio"/>	(4) almost always <input type="radio"/>
Go away by yourself and think about why you feel this way	(1) almost never <input type="radio"/>	(2) sometimes <input type="radio"/>	(3) often <input type="radio"/>	(4) almost always <input type="radio"/>
Write down what you are thinking and analyze it	(1) almost never <input type="radio"/>	(2) sometimes <input type="radio"/>	(3) often <input type="radio"/>	(4) almost always <input type="radio"/>

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	(1) almost never	(2) sometimes	(3) often	(4) almost always
Go some place alone to think about your feelings	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

	(1) almost never	(2) sometimes	(3) often	(4) almost always
Isolate yourself and think about the reasons why you feel sad	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>